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ABSTRACT

The intent of this theoretical paper is to recast our ideas about teaching mathematics as a result of an extensive research review on teaching behaviors. The product of this review is an explanatory curricular model which takes into account the content being taught. The purpose of studying teaching from a curricular perspective and the constructs and experience which the literature review was based on is outlined in the initial chapter. The next six chapters examine the contemporary literature with respect to some basic categories assumed to relate to teaching mathematics. These categories include content, motivation, planning, classroom events, pupil outcomes and pursuits, and teacher and pupil background. Finally, in the concluding chapter we summarize the information and present a model based upon the review. The model of pedagogy presented in that last chapter should provide researchers a set of constructs which can be used to study the teaching of mathematics. (Author)

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Research on Teaching from a Curricular Perspective

by Thomas A. Romberg, Marian Small, and Richard Carnahan

December 1979

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Theoretical Paper No. 81

RESEARCH ON TEACHING FROM A CURRICULAR PERSPECTIVE

by
Thomas A. Romberg, Marian Small,
and Richard Carnahan

Report from the Project on
Studies in Mathematics

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Abstract

The intent of this theoretical paper is to recast our ideas about teaching mathematics as a result of an extensive research review on teaching behaviors. The product of this review is an explanatory curricular model which takes into account the content being taught. The purpose of studying teaching from a curricular perspective and the constructs and experience which the literature review was based on is outlined in the initial chapter. The next six chapters examine the contemporary literature with respect to some basic categories assumed to relate to teaching mathematics. These categories include: content, motivation, planning, classroom events, pupil outcomes and pursuits, and teacher and pupil background. Finally, in the concluding chapter we summarize the information and present a model based upon the review. The model of pedagogy presented in that last chapter should provide reseachers a set of constructs which can be used to study the teaching of mathematics.

V

CLASSROOM EVENTS

by

Marian S. Small

An enormous amount of information can be gathered about what is happening in one classroom during one lesson. As Good and Power (1976) suggest, data can be procured about information, task, response, feedback, structural and temporal properties, and each of these categories can be described in many ways. For example, among feedback properties, one can observe the source, target, wait time, informativeness, length, and sign. To study instruction and look for behavior patterns over a long period of time is an even bigger task. Brophy and Evertson (1974) studied 59 second- and third-grade classrooms over 2 years; reports of their results included information about 171 low-inference interaction variables (Crawford, Brophy, Evertson, & Coulter, 1977). Tikunoff, Berliner, and Rist (1975), in reporting on an ethnographic study of 40 classrooms from the BTES sample, listed 61 different characteristics of teachers and pupils that showed up in classroom protocols. Of these, 21 including warmth of climate, spontaneity of the teacher, engagement levels of students, and consistency of the teacher, discriminated between more and less effective instruction.

We look at some of these categories in our model and even fewer in the study currently under way. Much of the missing information, particularly that related to management attributes of the classroom, is potentially valuable in predicting effects of instruction. If, for example, a teacher must spend great amounts of time dealing with misbehaving students, less time is available for instruction. Even data about the general climate of a classroom whether it is quiet and busy or how the teacher treats the pupils, can be useful in understanding how that classroom functions. However, we have chosen to concentrate primarily on variables involved directly with transmitting the subject matter content since those variables are most directly related to pupil learning. We have chosen to ignore almost all nonverbal teacher behaviors except those describing organization such as determination of group sizes for instruction. This is primarily because interpretation of such behaviors by observers is generally too subjective and unreliable. We do not ignore all pupil nonverbal behaviors, however. When determining a student's involvement in learning mathematics, we take account of both verbal and nonverbal indications of engagement.

Earlier in this paper, we discussed how content, teacher planning, and motivation affect the organizational and interactive environments, as well as the amount of time allocated for instruction. Variability in these factors, in turn, is hypothesized to influence variability in pupil engaged time. To describe classroom events, we have generated a set of low-inference behaviors which can be coded by classroom observers. We are aware that certain high-inference variables, such as clarity of instruction, are invariably positively associated with effective teaching from the point of view of the resulting student product (Rosenshine, 1971). We believe, however, that objective data can be more reliably obtained from classroom observers, and that this type of data is more useful in generating information which can be explained to teachers and used by them. We examine both the sequence and frequency of behaviors, although we cannot measure finely enough to recognize the one critical statement made at just the right moment by a given child. Our choice of behaviors to observe is based on previous research, and will be discussed in more detail in the following sections. We emphasize the importance of considering quality of instruction throughout our discussion.

Organizational Environment

A great deal of data is necessary to describe the organizational environment of a classroom. This ranges from information about the media used in teaching, such as television, texts, or computer-assisted instruction, to information about the school and about the grouping plan for a particular day. Although many studies have compared the effectiveness of various types of media in producing student learning (Jamison, Suppes, & Wells, 1974), we use only the most common situation which is 15 to 40 youngsters and their teacher supported by textual and perhaps manipulative materials.

We do not deal with the effects of the nature of the school on classroom events. We ignore data on community involvement, socio-economic status, and the like. These variables are important, but are related to variables discussed in Chapter VII in the section called "Pupil Characteristics." We recognize certain essential differences between schools which are organizational rather than environmental and that these affect teacher decisions about organizing the classroom. Romberg adapted Perrow's (Anglin, 1976) organizational theory and suggested that there are four types of schools, varying along two dimensions. The variations are based on whether students are treated as uniform and whether the instructional process is seen as more of an art or a science. The perceived need for individualizing instruction and the teacher's definition of his or her role in the classroom are obviously affected by which type of school the classroom is found in. In other words, a teacher situated in one of these four types of schools operates under a set of constraints which partially delimits the choices he or she can make in organizing instruction, particularly in the areas of grouping and structuring.

The choices a teacher makes in organizing the pupils and classroom are important in predicting the nature of student-teacher interactions, peer interactions, and pupil otucomes. Obviously, a teacher who does not organize instruction well by forcing children to wait for help or planning activities that require long set-up times during what should be learning time, will minimize the amount of time students are engaged in learning.

Organization, as defined here, involves the level of teacher control of the learning situation, the frequency and sequence of teacher-directed as opposed to independent work, the variety of learning activities, the degree of teacher monitoring of student activity, the sizes and types of pupil grouping, the presence or absence of manipulatives and other learning aids, and the levels of teacher and student mobility. Several concepts described by Kounin (1970) are also part of the organizational environment. In particular, momentum, the absence of teacher behaviors which slow the pace of the lesson, and accountability, how much the teacher holds children responsible for their performances, would be expected to affect engagement. These are not specifically studies here, however, since they are considered as primarily aspects of classroom management.

The first aspect of classroom organization we consider is the amount of teacher control over learning options, pacing, and verbal interactions. This can vary substantially depending on the type of pupil outcomes sought, the personal characteristics of the pupils or teacher, the institutional characteristics of a particular school, or the type of content being taught.

In some cases, community policy or a staff agreement may dictate the level of structuring in a school for virtually all learning activities occurring in that school. In other cases, the level of control varies with activities, where the teacher allows the content being taught to determine his or her structuring of the activity. For example, one aspect of structuring is control over student options. Since some content can be learned in a variety of ways, the teacher may allow each student to choose the activity he or she prefers to gain the necessary understanding of the required material. In other cases, this is not possible and the teacher cannot allow choices. Review material is also more likely to be left unstructured than new material since the teacher probably believes that students require less guidance with old material.

Peterson (1978), in reviewing the literature on open learning environments as opposed to highly structured ones, finds that on the average, direct, highly controlled instruction may be slightly superior for increasing pupil achievement. A less structured environment appears to be a better choice for promoting creativity, independence, curiosity, and a good attitude toward school and learning. Thus, the level of instructional control is likely to vary among teachers and schools depending on how desirable certain of these pupil outcomes are to those teachers or schools. One would expect that some combination of structured and unstructured activities would be necessary for achieving a balance of desirable educational outcomes. Peterson suggests that the degree of structuring should vary from child to child, depending on certain pupil characteristics, perhaps students' attitudes to various structures. Pupils would be placed in the appropriate environment for their own best growth. Similarly, certain types of teachers may operate more effectively in either less or more structured classrooms; each teacher probably creates the best possible situation for himself or herself.

Rosenshine (1971) reviewed studies on the pupil's level of control over learning options. He reported that allowing students a choice among tasks appears to be dysfunctional, although allowing choice of behavior such as where to work, does not. Based on these and other studies, he later advocated direct instruction with high levels of teacher control since he believed that this would produce high levels of engaged time (Rosenshine, 1976).

In a study with low socioeconomic status students in grades one and two, Soar (1973) found that total structured time correlated positively with reading and arithmetic gains for both high and low complexity outcomes. He used scores on seven different language arts and four arithmetic standardized tests as well as several scales specially designed for the study to measure achievement gains. This structured time included time on seatwork and time with the teacher in a large group setting. He found that structured time with the teacher correlated negatively with low complexity outcomes in both subjects in grades one and two, but positively with high complexity outcomes in grade two. This may reflect the importance of independent seatwork in practicing low level skills in elementary school subject areas. In discussing this and other studies, Soar and Soar (1976) reported a trend which shows that:

> . . . the most closely structured learning activities tended to relate to gain in low cognitive level learning outcomes. Measures which reflected a structure affording some degree of control and yet some degree of pupil initiative appeared to relate to gain measures at higher cognitive levels. (p. 263)

Soar, like Peterson, suggests that pupils may differ in the kind of classroom environment in which they function best.

Grannis (1978) reported on 20 second-grade children, most of them placed in Project Follow Through classrooms in four different programs. Each was observed 1 full day and information about the pupil was coded every 30 seconds. Grannis looked at the source of control (student, teacher, or joint) of task options, pacing, materials feedback, and expected learner interaction and the resulting levels of student engagement. He found that control of options by the teacher varied from 21% to 66%. On the other hand, pacing and materials feedback control varied very little between classes. Figures on teacher control of pacing ranged only from 21% to 51% and teacher control of feedback from 47% to 64%. Few instances of joint control were observed for any category.

The most important result of Grannis's study is the positive relationship he found between consistency of control in the various categories and high levels of student engagement. Grannis noted that high levels of engagement can occur with either teacher or learner control of options if pace, materials feedback, and learner interactions are controlled by the same party. In an earlier paper, Grannis suggested that each type of control option was associated with a certain educational goal. Teacher control was thought to be related to community goals, with the individual being of less importance than the general group. Learner control was related to goals of individualization, with individual needs taking priority. He suggested that joint control was related to goals of competence. Grannis hypothesized that the presence of a certain set of controls signals the purpose of an activity to students and that the congruence of purpose and appropriate structure is important for achieving the intended goals. Thus, consistency of control is likely to provide unambiguous information and students, understanding their task, are likely to be engaged.

We are left with the impression after reviewing these papers that the effective teacher varies the structure of an activity to try to meet individual needs taking into account the content being taught and the appropriate structure for that content. It is unlikely that only direct instruction or only a totally open environment is desirable, even if one or the other produces high levels of engaged time for particular students.

Based on the findings reported here, we have decided in our current study to judge whether the target student being observed is engaged in a structured activity or an unstructured one at each sample moment coded. We define an unstructured activity as one of the learner's own choice where he or she is allowed to determine what the activity is and how to carry it out. We do not separately code an activity option when the method of carrying out the activity is highly structured since the content is not under student control. Unfortunately, the appropriateness of the structure cannot be judged bacause so many pupil, teacher, and content characteristics enter into such a judgment.

Besides limiting student options, teachers can attempt to control the way students think about certain content. This can or should vary with the content taught, certain teacher characteristics, or even grade level. We believe each structured learning activity can be rated in terms of the teacher's attempt to routinize student learning and limit the thinking processes used by his or her students during the course of that activity. We also believe the degree of routinization achieved affects the kinds of questions and structuring comments offered by teachers as well as the responses made by pupils. Examples of attempts to control pupils' thinking are abundant. Suppose students are asked to work on word problems, but not allowed to solve the problems and display the answers in their own way. The teacher demands that students write open sentences of the form X + Y = Z or X - Y = Z for each problem and then solve it. In this way, the pupil's thinking is molded into a predetermined pattern. This attempt to routinize instruction is appropriate in some instances and not others. The appropriateness of the teacher's actions in this regard should be measured along with simple frequency counts of whether content is taught algorithmically.

Another aspect of classroom organization is the extent to which pupils engage in independent work versus teacher-directed instruction. Teacher decisions about the frequency and sequence of teacher-directed as opposed to independent work will normally depend on the nature of the content, information about individual pupils, and personal biases. One would expect a mix of these two organizations for high quality instruction. Sometimes an unchanging pattern of organization is deliberate, however. For example, Good and Grouws (1977a) advocate teacher-directed developmental work for a substantial portion of each class period followed by independent practice by the students. They have found this highly effective in producing student achievement in mathematics.

In other classes, the teacher may examine the content daily and decide whether a particular objective is best taught through independent work or through teacher-directed instruction. This may be influenced by the readability of learning materials, previous experiences with teaching that content, suggestions made in a teacher's guide, or the teacher's awareness of and belief in certain learning principles. In other classes, the teacher may simply make a decision based on personal convenience. We would expect the pattern of teacher-centered and independent work to predict interactive behavior and pupil engaged time, especially in light of BTES results which showed independent work most valuable for grade five reading, but whole class or group work best for grade five mathematics and for grade two work in both subject areas (McDonald, 1977).

The reasons for assigning independent work can vary. According to Bloom (1971), independent work allows a pupil the opportunity to master content at his or her own pace. Bloom reasons that a pupil is more likely to attend to work geared to his or her own pace and not to some arbitrary reference group within the class. From the point of view of many mathematics curriculum developers, a child learns by doing (Biggs & MacLean, 1969). This, too, implies a fairly large component of independent work.

Usually, the phrase "independent work" is really a synonym for what we call "seatwork." Rosenshine (1976) reported that, by far, more time is spent on seatwork in grades two and five than on any other reading or arithmetic activity. Brophy and Evertson (1974) found that amount of seatwork in grades two and three correlates positively with gains on standardized word discrimination and spelling tests. Yet BTES results (Fisher et al., 1978) indicated that seatwork is sometimes associated with low levels of engagement, where we might expect lesser gains in achievement.

One reason students may be off-task during seatwork is the teacher's failure to monitor students during this time. Harnischfeger and Wiley (1978a) hypothesized in their model of school learning that teacher surveillance determines task involvement. BTES (Fisher et al., 1978) results indicated that frequency of monitoring, which includes both academic observation and questioning, is positively correlated with engagement. Good and Grouws (1977a) also emphasized the importance of monitoring student seatwork.

Another problem with seatwork is the student's inability to proceed if he or she is confused. Crawford and Gage (1977) point our the importance of clear directions when assigning independent work. Lack of clarity can cause a student to wait for help, which results in further off-task behavior. In our present study, we intend to record each moment sampled whether a student is engaged in independent work or not.

We recognize that a student's engagement may be affected by how appropriately an activity is organized, although we do not judge appropriateness in our present study. For example, if a teacher's objective is to diagnose pupil performance on number facts and he or she has each student only answer one question while the others wait for their turn, we will see a lot of off-task behavior. To some extent, appropriateness of organization can be determined a priori by examining the content being taught. On the other hand, after an activity is completed, one may say the organization was appropriate if students all seemed to pay attention and learn from the activity. This does not necessarily say the organization was optimal, of course.

We observe teacher monitoring of students indirectly by recording the teacher's verbal interactions during independent pupil work. In this way we can observe feedback and questioning, the normal verbal evidence of monitoring. Nonverbal monitoring may be an important variable, too. Unfortunately, we will not detect this in the present study.

In our model, we assume the timing of a behavior is as important as the amount of that behavior. Therefore, we would expect the relative amounts of teacher-directed and independent work to predict interactive behavior and pupil engagement, and also the timing of these situations. We determine whether independent activities follow or precede teacher-directed learning for a given activity or whether objectives are met only through one of these approaches. Appropriate timing for different organizations influences engagement, too, but this is not measured in our present study.

A third element of organization is the teacher's choice of how many activities a student or class will attempt to deal with in one learning period. In some instances, variety is beneficial. Some students may be more prepared for certain content and may require different learning activities. Faster students should have other activities available which deal with the subject content and maximize their opportunity to learn. Students may get bored with certain types of tasks and variety can maintain their interest. Good and Grouws (1977b) advocate that each mathematics period be divided into several sections: review of previous work, development, and seatwork. They found that this type of teaching strategy proved highly effective in elementary school mathematics.

On the other hand, some studies indicated that classes operate better with fewer activities for any single lesson. Scott

(1977), in a study of preschool teachers, found observational records for more effective teachers, as identified by supervisor ratings, showed fewer independent episodes than for less effective teachers. She suggested that the effective teacher's behavior was continuous and flowing rather than disjointed. McDonald (1975) reported that variety of instructional materials is negatively correlated with achievement on standardized mathematics tests in the BTES sample. Stallings and Kaskowitz (1974) reported a negative association between number of activities in a day and arithmetic scores on the Metropolitan Achievement Test. We suspect that where a variety of activities occur simultaneously or a variety of materials are used, students may work in unsupervised small groups, listen to irrelevant directions, or wait for their own directions. In addition, if more time is necessary for giving sequential directions, then less time is available for content, and achievement will suffer.

A teacher must balance these advantages and disadvantages and consider the nature of the content when organizing the day's instruction. We will observe the number of activities in each learning period during the current study and hypothesize that variability here is predictive of variability in pupil engagement.

The structure and function of pupil grouping affects types of communication and task involvement. Although the teacher may implicitly define a group of students, as when a teacher chooses a reference group to base the pacing of a lesson on (Dahllof, 1971), we look only at explicit grouping structure and function.

Harnischfeger and Wiley (1978a) distinguish between small group, large group, and individual work in their model of school learning. Although we have already examined some evidence indicating the relative effectiveness of individual and teacher-directed situations, further distinctions between small and large group settings can be made in light of other research results.

Medley (1977) summarized the results of several studies by saying that the teacher who maximizes large group instruction sees the greatest gains in pupil achievement. For grade three pupils, Stallings and Kaskowitz (1974) reported positive correlations for large group instruction with arithmetic and reading gains and negative correlations for small group instruction with outcome gains. However, they found small group instruction was effective at the grade one level. Soar (1973) reported negative correlations for small group work without a teacher present with outcome gains. His sample was comprised of grade one and two students. Good and Grouws (1977a) found that third-, fourth-, and fifth-grade students appear to benefit more from whole class than from small group instruction. They also observed that teachers using whole class instruction most generally fell at either extreme in terms of their classes' residual achievement gains in mathematics. None of these studies attempted to determine whether the type of content had any bearing on the effectiveness of a small group organization.

We know that learning time in most schools is spent in large group or independent and not small group work (Gump, 1967; Stallings & Kaskowtiz, 1974). Why do we find so little small group work? The grouping structure is likely to affect the amount of verbal interaction among peers, as well as the level of involvement. More peer interaction about content occurs in small groups, but so does more off-task talking. Also, the teacher can only deal with one small group at a time and off-task waiting time is increased for students in other groups.

In spite of these disadvantages, small group instruction has a place in the classroom. Soar (1978) suggested that when students are attentive to their tasks a small group organization is very effective. Small groups teach children to cooperate with and learn from each other. Instruction may be tailored to groups of students with different entry behaviors or to groups with different outcome goals. And tasks requiring different equipment may be shared in small groups.

How do teachers form groups? Grouping criteria can be based on student abilities, personalities, or interests. Groups can be formed because certain youngsters have difficulty with a particular problem. In our interviews with teachers in the current study, we will ask what criteria they use in forming groups. In our observations, we code group size for each learning activity for each student sampled.

Literature in mathematics education has stressed the importance of manipulatives in teaching mathematical ideas to young children. Much of the stress is based on work by Piaget (Copeland, 1976) which indicates that at certain levels of development, concrete understanding of concepts may be achieved although more formal understanding may not. For example, the student may be unable to multiply 38 by 22 unless he or she has materials such as rods and cubes available. Of course, the materials should be appropriate to the task. Physical materials also provide the student with immediate feedback which correlates positively with achievement gains (Fisher et al., 1978). The use of materials affects the types of comments teachers make and the students' potential to handle tasks without teacher assistance. Thus, in our current study, we distinguish among lessons using few, some, or many manipulatives.

A final aspect of organization which we address is the level of teacher and pupil mobility. Stallings and Kaskowitz (1974) reported that more effective teachers show higher mobility, yet BTES results (McDonald & Elias, 1976) suggested that effective teachers spend more time at their desks than less effective ones.

Soar (1977) found that much physical movement in the classroom related negatively to both cognitive and affective outcomes, but Brophy and Evertson (1977) reported that allowing pupils to move about with permission is effective. Given the conflicting evidence, we believe that student and teacher mobility should be considered.

In summary, we have chosen to measure the organizational environment of the classroom in terms of: (a) whether the student is engaged in a structured activity; (b) whether an activity is taught algorithmically and whether this is appropriate for a given objective; (c) the timing, amounts, and appropriateness of teacher-directed and independent work; (d) the extent of teacher monitoring of independent work; (c) the variety of learning activities in a given lesson and over the course of a topic; (f) the grouping of students--large, small, or individual--and teacher criteria for determining grouping; (g) the extent and appropriateness of physical materials; and (h) the levels of student and teacher mobility. We expect these measures to predict pupil engagement and the kind and amount of verbal interaction in the classroom. Variability in organizational environment should be an important factor in predicting teaching effectiveness (Carroll, 1963). A great deal of literature can be found on the importance of individualizing instruction. We believe most teachers vary organization, content, and time allocations to meet individual needs. We have chosen not to measure degree of individualization separately. We expect that effective teachers change organizational strategy in response to learner needs, and in the current study we observe these changes.

Interaction Environment

General Data about Interactions

Many studies describe and analyze verbal classroom behavior (Bellack, Kleibard, Hyman, & Smith, 1966). We are interested in general information about verbalization such as how much talk there is, who talks to whom, and whether the talk centers on the content or on directions relating to the content.

Unfortunately, we cannot focus on clarity and appropriateness of verbal behavior in our current study, but must concentrate on frequency and type of communication. Rosenshine (1968) measured clarity through low-inference variables such as verbal fluency and the number of explanatory links used by the teacher. Wright and Nuthall (1970) studied the clarity of questions by counting the number of times a teacher's question was immediately followed by another question or additional information from the teacher. As a high-inference variable, clarity ratings have been linked to pupil growth by some researchers (Good & Grouws, 1975; Rosenshine

& Furst, 1971), but not by others (Brophy & Evertson, 1974). We believe more detailed study of clarity and appropriateness of teacher verbalizations is necessary.

Teacher verbalizations comprise one half to two thirds of all classroom interaction time (Furst & Amidon, 1967), but the amount is usually not significantly related to pupil achievement (Dunkin & Biddle, 1974). Stallings and Kaskowitz (1974) reported a significantly positive relationship between total academic verbal interactions and achievement in grade one. As Gage and Berliner (1975) point out, most correlations of verbal interaction with pupil achievement are positive, but not significant. Although the percentage of teacher talk may appear to be high, the low correlations indicate that teachers do not talk enough to increase achievement.

The amount of talk by any one student is normally quite low. Fortune, Gage, and Shutes (1966) found that amount of pupil talk is unrelated to pupil achievement. Information on peer interaction may be useful, though, in providing insights into the learning process. Grannis (1978) observed that task engagement levels were only slightly lower if learner interactions were deemed appropriate than when they were forbidden. In other words, if students are expected to talk to each other about a task, they will do so. In many classrooms this may make a tremendous difference. It students are expected to interact, pupils will not need to wait for teacher help as often since another student can help them. In this study, we will not analyze student verbal behavior beyond noting whether it is related to mathematical content, since teacher talk has the greatest effect on pupil pursuits. We recognize, however, that student verbal behavior is an important area for future research.

Soar (1973) found that steady-state teacher talk, as opposed to pupil talk, correlated negatively with reading and arithmetic gains on low-level items in grade one, but positively with gains on high-level items in grade two. Perhaps this is related to the pupil's need to practice low-level skills independently, whereas higher level knowledge requires more input and organization from someone with a broad overview of the content. The West Georgia College Project (Coker, Lorentz, & Coker, 1976) found that teacher lecturing, even when pupils were bored, correlated positively with both high- and low-level reading gains on the Comprehensive Test of Basic Skills in grade two. The reason for these inconsistent results is unclear.

Stallings and Kaskowitz (1974) found that the amount of time the teacher talked to only one or two students correlated negatively with class achievement in grades one and three mathematics. Perhaps this reflects the inefficiency of communicating to individuals when the interests of a large group must be served. Of course, teachers probably spend more time helping individuals in a low ability group where achievement gains are less likely.

Several researchers have observed who initiates verbal interactions as opposed to who responds. The West Georgia College study (Coker et al., 1976) reported negative correlations of pupil-initiated exchanges with achievement in grades one to three for both reading and arithmetic, but positive correlations in grades three to twelve. Stallings and Kaskowitz (1974) reported negative correlations of pupil task-related comments with achievement in grade three, but Brophy and Evertson (1977) found student initiation was positively associated with learning in grades one and two unless answers were called out. Good and Grouws (1975) and Good, Sikes, and Brophy (1973) also found high pupil achievement associated with greater amounts of pupil initiation. Again, in the present study and model, we did not concentrate on the initiation of verbal interchanges, the correctness of pupil responses and subsequent teacher reactions, or whether pupil talk was voluntary.

We believe a necessary distinction to make is between the content itself and the directions involved in teaching that content. Large amounts of time devoted to directions detract from the student's engagement with the content. Too little direction giving forces the student to waste considerable amounts of time and energy determining what to do.

Based on data from Dahllof and Lundgren (1970), Furst (1967), and Tisher (1970), direction giving occupies about 10% of classroom interaction time. Amidon and Giammatteo (1967) found that teachers rated as "superior" exhibit less use of directions than others. However, BTES results (Fisher et al., 1978) showed that teachers who give directions more often and spend more time on structuring the lesson consistently had students showing a higher success rate.

We believe the nature of the content affects the amount of direction giving required. This will reflect the relative amounts of time spent on content as opposed to directions. We also make a distinction between exposition and questions as a measure of the teacher's attempts to encourage student participation.

In the present study, we will record interactions for our target students in terms of: (a) direction, that is who is speaking to whom; and (b) the other participants, teacher, student, or other adult. For the teacher, we will record interactions in terms of: (a) direction, whether the teacher is speaking or listening; (b) whether the teacher is speaking to a small group, large group, or an individual student; and (c) whether the verbalization is a question. For both teacher and pupils, we will observe whether the interaction is one regarding mathematics content, directions related to that content, or neither. In attempting to further classify teacher verbalizations, we want to observe in detail three of the four types of pedagogical moves outlined by Bellack (1966)--structuring, soliciting, and reacting.

Structuring

Berliner and Rosenshine (1976) found that more effective teachers make more extensive use of structuring comments than less effective ones. They tend to make their students aware of how a particular question, explanation, or activity fits into a larger framework. Ausubel (1968) and others have indicated the importance of organizers in learning. We have decided to distinquish between task and content structuring. We believe the relevant information about task structuring is captured in the amount of time devoted to direction giving; therefore, we wish to concentrate on content structuring.

Bellack (1966) reported that in his observations of 60 high school social studies lessons, 11.2% of the verbal interaction was structuring and, of that, 86% was done by teachers. In other words, teachers do little content structuring and students do even less.

Wright and Nuthall (1970) observed teacher behaviors as they taught science lessons at the grade three level over a 1-week period. They found no overall relationship between structuring and achievement, but there was a positive relationship between structuring at the end of an episode and achievement and a negative relationship between structuring following a question and achievement. They hypothesized that the negative relationship may reflect the lack of clarity of the question.

The staff on the Program on Teaching Effectiveness at Stanford (SCRDT) (1976) also found that high levels of structuring produced higher levels of achievement on certain items. High structuring effectively led to higher scores on low-order items based on material taught exclusively by the teacher. Structuring in their study involved reviewing main ideas, stating objectives, outlining lesson content, signaling transitions between parts of a lesson, indicating important points in a lesson, and summarizing parts of the lesson during its course. The Stanford group found that high levels of structuring also contributed to higher levels of retention. The effect was less pronounced, though, when student learning was based on textual material as well as teacher presentation. It was most pronounced, again, for lower level skills taught by the teacher only. Student perception of structuring as measured on a treatment perception scale was greater than the direct effect of teacher structuring (Staybrook, Corno, & Winne, 1978).

Perham (1974) found that structuring comments at the beginning and end of a lesson were positively related to low level arithmetic gains for kindergarten and grade one students. Examples of structuring in her study included identifying objectives, relating content to previous work, summarizing, and discussing student work at the conclusion of a lesson. BTES results showed that structuring correlates positively with academic learning time (Fisher et al., 1978) in grades two and five. Direction giving was included in their definition of structure, however.

Awareness of the purpose of a task or its essential elements assists a student in remaining on task. We cannot read each child's mind, but we can measure the overall effects of different types of structuring on pupil engagement. Teachers can help students see the relevance of particular tasks. They can also summarize material if careful not to reduce procedures and concepts to sets of rules which do not always apply. Another type of structuring comment which may predict engagement is to announce the relative importance of a particular activity or topic. Similarly, structuring that includes signals indicating transitions between lesson parts correlates positively with achievement (Program on Teaching Effectiveness, SCRDT, 1976).

We posit three categories of structuring to be important in predicting pupil behaviors: (a) relating work to past or future learning; (b) outlining objectives of an activity; and (c) summarizing or reviewing content. We believe their effects are mediated by pupil perception of these statements.

Soliciting

Teachers vary in the amount of questioning and the types of questions they ask. This variation can be explained in part by the nature of the content being taught. Dunkin and Biddle (1974), in a review of studies, reported classroom interaction in the form of teacher questions ranged from 10% to 16%. Bellack, Kleibard, Hyman, and Smith (1966) reported questioning amounted to 20.2% of the total amount of classroom talk. He found that about 60% of a teacher's questions are substantive as opposed to simply task-related. These figures are surprisingly low since questioning is one of the teacher's main vehicles for actively involving students in learning, for diagnosing student understanding, and for keeping students on task.

A positive relationship between teacher use of questions and pupil achievement have been found in some studies and a negative one in others. For example, Stallings and Kaskowitz (1974) found the number of questions asked was higher in effective teachers' classes, yet Brophy and Evertson (1974) found the percentage of opportunities for pupil response per unit of time was lower in effective teachers' classrooms. They also found frequency of questions was more important to high than to low socioeconomic status pupils.

The cognitive level of teacher questions, that is, the extent to which questions require students to go beyond simple recall of information is important. Consistent results show that effective teachers of low socioeconomic students ask more low-level questions than less effective teachers (Soar, 1973; Soar & Soar, 1972; Stallings & Kaskowtiz, 1974). Effective teachers also ask fewer high-level questions.

Recently, Gall et al. (1978) reported on a controlled experiment to study the effects of the level of teacher questions. Treatments differed in the proportion of high-order and low-order questions. One treatment consisted of 25% high-order and 75% low-order, one of 50% high-order and 50% low-order, and one of 75% high-order and 25% low-order questions. The results indicated that the middle treatment led to the least gains in achievement with the other two equally effective. The Stanford group (Program on Teaching Effectiveness, SCRDT, 1976) suggests that these results help explain the inconsistent results of previous experiments. Many high-order questions may be valuable when few low-order questions are asked, but not if the mixture is more even. Grannis (1978) helped explain the results of Gall et al. (1978). Grannis found that consistency among various facets of the learning environment is associated with higher levels of engagement. In a consistent situation the student knows what to expect and spends energy on learning. If a student expects mostly high- or low-order questions rather than an even mix, he or she feels secure and this is reflected in performance.

Winne and Marx (1977) suggest that the apparent ineffectiveness of high-order questions may be caused by not viewing the teacher as a decision maker. The teacher may not ask a high-order question of a particular student because that student was not ready for such a question. Thus, although high-order questions are valuable, research results associate low-order questions more positively with achievement.

Joyce (1975b) reported that the more teachers use high-order questions, the more students use high-order processes. But in three studies, Soar (1977) found negative correlations between teacher-pupil interactions at a high cognitive level and achievement gains, even on complex measures. Brophy and Evertson (1974) reported mixed findings, but found high-level questions were beneficial in high socioeconomic status classes.

Good and Grouws (1977b) recommend that teachers use product questions rather than process questions for several reasons. They suggest that by eliciting a quick response, the teacher can cover more material, provide more students with an opportunity to speak, and diagnose more difficulties. In addition, easy questions (usually product questions) provide more success.

The Stanford group (Program on Teaching Effectiveness, SCRDT, 1976) used soliciting as an independent variable in their experiment on structuring, soliciting, and reacting. They defined high soliciting as asking about 60% high-order questions and 40% low-order, and waiting at least 3 seconds before allowing any other question, response, or statement after asking a question, getting a response, or before calling on a second student. They defined low soliciting as asking about 15% high-order and 85% low-order questions, and waiting less than 3 seconds after asking a question or receiving a response for the next interaction. Results indicated that low soliciting was preferable on both low- and high-order items when the teacher was the only source of instruction and on low-order items when the teacher and text were sources. Level of soliciting made less difference on retention tests.

Although low-order questions are beneficial to students, some doubt about the effectiveness of high-order questions still exists. A decision about what type of questions to ask cannot be completely arbitrary, but must depend on the content being taught and the outcomes sought. Surely some high-order questions are necessary in a high quality program. The mix of high- and low-order questions may well affect pupil interest and engagement over a period of time. We will observe three main types of teacher questions: (a) *low-order* questions; (b) *high-order* questions; and (c) *management* questions directly related to content.

This last type of question maintains the distinction between solicitations regarding substantive matters and those regarding directions. We will observe the effects of *amounts and sequencing of various types of questions* on engagement. In the current study, we are unable to collect data on *wait time after questioning* or take low-inference measures of *question clarity* and *appropriateness*, primarily because of our sampling technique for coding data.

Reacting

According to Bellack et al. (1966), the third type of pedagogical move is reacting. Reacting moves are behaviors occurring after a pupil response. A teacher may simply provide praise, criticism, or neutral feedback. A teacher may also use student ideas, probe for more information, or change instructional strategy as a result of particular responses. Bellack et al. found that 25% of all spoken lines were reacting moves, but this large figure was due to length rather than frequency of reaction

This figure included both teacher and pupil reacting; we concentrate only on the former. About 46% of reacting moves were reported as ratings, although about 27% combined ratings and substantive information.

Some studies have separated task engagement feedback from actual academic feedback. BTES (Fisher et al., 1978) results indicated that while task management feedback is negatively correlated with engagement, academic feedback shows a positive relationship with engagement. Stallings and Kaskowitz (1974) reported a negative relationship between task-related nonacademic feedback and achievement in grade three, but a positive relationship between total amount of feedback and achievement in grade one. These results are not surprising. Task engagement feedback is given primarily for off-task behavior. We are not dealing with management aspects of the classroom; therefore, we will only present academic feedback in our model of instruction.

A particular type of teacher reaction is an unplanned change in strategy based on pupil responses. This is one aspect of what BTES (Fisher et al., 1978) termed the teacher's ability to prescribe. Two other aspects of this ability involve goal directedness and flexibility in use of instructional materials. They found the ability to change strategy, when combined with flexibility, was positively related to academic learning time in grade five. We include use of strategy changes in our model as a possible predictor of pupil engagement.

The effects of length, informativeness, and immediacy of feedback have been studied by several researchers. Brophy and Evertson (1974) suggested that, in general, lengthy feedback to pupil questions is counterproductive in grades two and three. Brief feedback was useful in mathematics, but not in reading, and particularly valuable for high socioeconomic status pupils. Failure to give any feedback for a correct answer correlated negatively with achievement in arithmetic, but positively with achievement in reading. Perhaps in arithmetic students are more at a loss to decide if they are correct without teacher assistance. Good and Grouws (1977b) also advocate short feedback to keep engagement high. They suggest that pupils be provided with feedback within 1 minute of the start of a practice assignment. Crawford and Gage (1977) recommended that teachers provide brief feedback for high ability students, but that they vary the length of feedback for low ability students.

With our time sampling technique, we will not be able to observe feedback length in the present study. However, we can observe the informativeness of feedback, which we expect correlates highly with length. Although Zahorik (1968) suggested that teacher feedback is rarely informative, a number of researchers have observed and experimented with this type of feedback. The Stanford group (Program on Teaching Effectiveness, SCRDT) varied level of reaction in their 1976 study. Teachers in the high reacting condition provided informative feedback, prompting, and praise, whereas teachers in the low reacting condition provided little information and a neutral reaction. High reacting, in combination with high structuring, was particularly effective in terms of pupil achievement and student perception of teacher reacting mediated the relationship between reacting and pupil achievement.

High information feedback generally involves elaboration of student ideas. Perham (1973) found a negative correlation between use of pupil ideas in grade one with low-order arithmetic achievement gains. The West Georgia Project (Coker et al., 1976) reported a positive correlation in grade two between helping pupils correct misconceptions (presumably a form of high information feedback) and arithmetic achievement. Dunkin and Biddle (1974) also report conflicting evidence on the effectiveness of certain types of high information feedback; however, most studies indicated that greater teacher acceptance of pupil ideas did not relate to achievement.

A third aspect of feedback we mentioned was immediacy. Brophy and Evertson (1977) reported that immediate feedback was most functional for low socioeconomic status students, but delayed feedback was better for high socioeconomic status students. This difference may be related to pupils' patience levels. We do not measure immediacy in our model.

A number of researchers have studied teacher use of praise and criticism. Dunkin and Biddle (1974) reported a large number of studies concluding that teacher praise is unrelated to pupil achievement, but others contradict this finding. Soar (1977) found that praise is effective for low socioeconomic status pupils. Wright and Nuthall (1970) also found that praise was positively related to achievement. Gage and Berliner (1975) suggest that praise does not hurt and may help and so should be encouraged.

Brophy and Evertson (1977) found that praise was effective with low socioeconomic status students, but was unrelated to achievement with high socioeconomic status pupils. They also found that criticism was negatively associated with achievement for low socioeconomic status students, but, in the main, positively associated with achievement for high socioeconomic status students. A number of other studies concluded that teacher criticism is unrelated to pupil achievement (Dunkin & Biddle, 1974). Rosenshine (1971) suggests that strong criticism has a negative effect, whereas mild criticism does not. We would normally expect to find little strong criticism in the elementary grades.

Doyle (1978) noted the inconsistency of teacher rating reactions. He refers to Bellack et al. (1966) who observed that about 20% of the correct answers coded in his study got negative ratings and about 79% of the incorrect answers got positive ratings. Doyle attributes this, in part, to the teacher's attempts to maintain control and keep things moving in the classroom. Thus, the teacher sometimes speaks hastily without carefully considering his or her words. The tendency to praise children whenever possible and not to criticize can also lead to this inconsistency. Brophy and Good (1970) showed that differential teacher expectations are associated with reacting. Teachers were more likely to praise students they expected correct responses from than students they did not. However, these same teachers were more likely to accept poor performance from the students for whom they had expectations. These inconsistencies may lead children to disregard much of a teacher's rating reactions, explaining the failure to find a significant relationship between teacher ratings and pupil achievement.

In summary, we do not include feedback length, prompting, and redirecting of questions in our model. We will observe, however: (a) the informativeness of feedback as either high or low information; (b) the absence of feedback when it is expected; (c) the sign of feedback as either positive, negative, or neutral; and (d) teacher strategy changes.

According to Bellack et al. the fourth type of pedagogical move is responding. Although many studies have looked at variables involved in responding, such as correctness of responses or congruity of response with question asked, we do not include this in our model of classroom events.

Explaining

Teachers often simply explain content or directions, without structuring, soliciting, or reacting. We know that much classroom talk falls in this category. We are interested in determining how variability here affects pupil engagement.

BTES (Fisher et al., 1978) reported separate statistics for planned teacher explanation and for explanation based on need. They found the former related positively to engagement and the latter related negatively. This suggests explanation based on need is rooted in situations where students are unable to proceed without assistance and often have to wait. We assume most explanations to an individual are based on need; therefore, we do not distinguish these two types of explanation in our model. We distinguish explanation in terms of the size of the group addressed by the teacher (individual student, small group, or large group). We expect to detect explanation based on need by noting when a teacher changes strategy.

We will record when the teacher: (a) explains content; or (b) explains directions. We use the word "explain" here broadly to imply any teacher exposition. Explanations can be elicited by pupil responses as teacher feedback, but need not be. Although we do not look at clarity of explanation in our present study, this is an important variable to consider in the model.

Allocated Time

In Carroll's (1963) model of school learning, the time allowed for learning is a critical variable in predicting achievement. Bloom's (1971) model of mastery learning also regards time as an important variable. Harnischfeger and Wiley (1978b) have pointed out that the time allocated for instruction can vary tremendously because of variability in number of school days per year, number of minutes of instruction per day, and teacher's characteristics in organizing classrooms. For example, in classes they observed, time taken for managerial tasks varied from 18 to 90 minutes per day. Dishaw (1977) reported great variations in student opportunity to learn in the BTES sample. Some teachers allot less than 25 minutes per day on the average to mathematics instruction and then use up much of this in "cleaning up" from previous work. Some teachers also tend to cancel their math period as opposed to, say, a reading period for special events or projects. If students lack the opportunity to learn certain content, high levels of achievement on that content cannot be expected.

Clearly, allocated time must partially predict pupil engaged time. The BTES Academic Learning Time model (Fisher et al., 1978) includes allocated time for learning activities as an important variable. In studying sample classrooms, they found that learning was positively correlated with allocated time. Stallings and Kaskowitz (1974) found that time spent on arithmetic correlated positively with high and low level arithmetic gains in grade three. Soar (1973) observed that the effective teacher of low socioeconomic status grade three pupils devoted more time to academic activities than the less effective teacher.

Obviously, differences in overall allocation of learning time in a subject can be substantial and important. The teacher may allocate time differently for various types of pupils, classes, or content. Therefore, we record the amount of available time and actual teaching time for each lesson in our study. The former measures the amount of time teachers plan to allot for teaching mathematics, whereas the latter deducts any periods of time used for fire drills, beginning and ending transition times, or other managerial classroom functions.

Harnischfeger and Wiley (1978a) list pacing of instruction, a variable related to allocated time, as a factor in pupil learning. Good, Grouws, and Beckerman (1978) studied pacing in mathematics. They based their work on earlier results of Dahllof

(1967) and Lundgren (1972) who found that a teacher appears to choose a steering group of pupils within the class as a guide to the proper teaching pace. The higher the level of the steering group, the more quickly material is covered. Good et al. reported that pace and, therefore, amount of material covered was a variable which differentiated between teachers defined as highly effective or relatively ineffective in terms of their pupils' performance on standardized mathematics tests over 2 consecutive years. Pupils of teachers who moved more quickly through the curriculum performed better.

Barr (1975) found that teachers who organized pupils into small groups paced these groups differently. Obviously, those who taught classes as a whole paced homogeneously. She pointed out that teachers who taught similar groups in terms of pupil ability paced differently and that teacher pacing remained stable from year to year. This suggests that the propensity to a certain pace is a characteristic of the teacher. She also found that influence of colleagues on pacing results in similar pacing within a school. In a study on learning sight vocabulary, Barr (1974) concluded that pace affects the level of learning beyond what one might expect on the basis of aptitude, with rapid pace associated with higher learning. This is confirmed in the Good et al. report.

In comparing self-pacing and teacher pacing in high school science, Arlin and Westbury (1976) found that teacher pacing tends to depress mean achievement and narrow variance in achievement. High ability students are affected most since teachers appear to set a pace better suited to lower ability students. Thus, the better students have less opportunity to learn. This suggests that independent work may be beneficial for good students. Unless, however, the teacher provides a continuous stream of activities, no advantage would be gained.

We suggest that pacing of instruction is an important variable in our model. The quickness and variability in pace are predicted by content demands, classroom organization, and teacher characteristics. In turn, pace differences can predict variability in engagement. If the pace is very slow for a certain class on one activity, we expect to see off-task behavior in the data on higher ability pupils.

In summary, we suggest that variability in three time-related measures is involved in predicting engaged time: (a) available time; (b) actual learning time; and (c) actual time per unit of instruction (instructional pace). We also measure whether these figures vary for different students to determine if the teacher is attempting to meet individual needs.

We do not attempt to deal with the measure of time needed to learn as suggested by Carroll (1963). This is a complex problem.

In part, the teacher may account for learner differences by varying available time for different pupils. However, a much more thorough investigation of the effect of time needed to learn on engagement is necessary in the future.

VI

PUPIL OUTCOMES AND PUPIL PURSUITS

by

Thomas A. Romberg

Schools are social institutions whose primary purpose is to transmit specific knowledge and skills to our young people and introduce them into our social system. Thus, one way of judging the quality of a school's instructional program is to assess how well students have acquired the expected knowledge, skills, and values. Identifying expected pupil outcomes and developing appropriate assessment procedures is a major task in all schooling research. In our original model (see Chapter I), these pupil outcomes were identified: acquisition of concepts and skills, maintenance of those concepts and skills, and preparation for new concepts and skills. Although these outcomes are essential, they do not exhaust the list of pupil outcomes we might usefully observe in assessing the way a particular curriculum unit has been taught.

The effects of all other aspects of instruction are mediated through what pupils do. For instance, central to other mathematical outcomes are pupils' math experiences. Thus, the subtle question--How can one determine if pupil actions are productive?--

becomes a key to the development of a workable model of instruction. In this chapter these two aspects of pupil actions in the model, pupil outcomes and pupil pursuits, are reviewed.

Pupil Outcomes

Any answer to the simple question--What are reasonable pupil outcomes following a set of instructional experiences in mathematics?--is of necessity quite complex. David Berliner in a paper titled "Impediments to the Study of Teacher Effectiveness" (1976) outlined several problems facing researchers who are examining the relationships between teacher behaviors and pupil performance. He discussed three problems concerning pupil outcomes: (a) the use of standardized tests, (b) the use of tests for curriculum units, and (c) multi-variate outcomes. To this list I have added one other issue, (d) the use of student outcome measures in making decisions.

Standardized testing. In studies of how teachers affect students, standardized achievement tests are extensively used to measure performance outcomes. These tests are generally reliable, have adequate curriculum content validity, and are predictive of future academic success. However, they have basic problems in that they rarely reflect what was taught in any one teacher's classroom. Also, they are highly correlated with standardized intelligence tests (whose items measure intellectual ability, not instructional outcomes) and are usually group administered multiple-choice tests. These, when used with young, bilingual, or lower socioeconomic status children, may yield biased results. On the whole, off-the-shelf standardized achievement tests make poor dependent variables for studies of teaching.

Tests for curriculum units. To insure that tests are content valid for a particular classroom, many investigators have either created or identified special curriculum units to study teaching (Berliner & Ward, 1974; Joyce, 1975b; Montgomery, 1973; Peterson & Janicki, 1979; Popham, 1971; Romberg & Gilbert, 1972). These curriculum units contain objectives, pupil activities, and test items. The teacher is asked to teach the objectives. Every teacher has similar materials and objectives. Students are pretested and posttested with tests designed to measure objectives of the curriculum unit. The dependent variable in this situation is undoubtedly more valid and more reactive to classroom teaching than are standardized tests (for example, see Filby, 1976). However, this methodology may not always show strong predictive validity over a long period of time. Berliner points out that the ranking of teachers on effectiveness, as determined by the relationships between student pretest and posttest scores associated with an experimental teaching unit, was only moderately correlated with a ranking of those teachers based on gains over the whole school year (Berliner & Rosenshine, 1976). Studying teacher effectiveness with dependent measures tied to special teaching units may not be a fair characterization of teaching over the long haul since teachers may not cover the same units during a year. But, unit tests are one way to identify teachers who differ in measured effectiveness when teaching a common curriculum, to common objectives, for controlled amounts of time.

Multivariate outcomes. There are a large number of dependent variables in any instructional interaction that interest any researcher. The first of these is the achievement of the learner in the situation. Achievement has been a commonly used measure of instructional outcomes. Actually, since instruction on objectives is spiral, gain in achievement is of primary interest. However, the problems of dealing with gain scores are beyond the scope of this paper (see Harris, 1962).

The second dependent variable in instructional settings is the maintenance of performance. Once concepts and skills have been achieved considerable time is spent in most classes attempting to maintain that level of performance. The third dependent variable I have called "preparation for new concepts and skills" (Romberg, 1979). The idea grows out of the notion of "savings transfer" (Cronbach, 1965). The learning of some things, often of limited importance in their own right, provide a basis for the acquisition of later concepts and skills. In this case, learning goes beyond the initial acquisition of specific concepts or skills to the rules, structure, or thought processes underlying those concepts or skills. Whether this preparatory outcome is different from initial achievement is debatable. However, studies such as Erlwanger's (1975) case study with Benny demonstrate that while Benny had acquired a number of mathematical skills he had little sense of their structure or uses.

The multivariate nature of dependent variables may also be illustrated with content by process matricies for objectives. Since the publication of The Taxonomy of Educational Objective: Cognitive Domain (Bloom, Ed.) in 1956, these matrices have been used to define basic categories of cognitive processes. They imply that the acquisition of concepts differs from the acquisition of skills and both differ from the use of concepts and skills to solve problems. Thus, these factors should be considered separate outcomes and assessed independently. When these processes are crossed with the type of content to be taught in a year such as addition, multiplication, fractions, geometry, the result is a tremendous set of specific outcomes. For example, in the National Longitudinal Study of Mathematical Abilities a

3 x 4 matrix (see Figure 13) was used to categorize outcome variables (Romberg & Wilson, 1969).

Another factor adding to this complexity is the learner's feelings about the instructional situation. Students are seldom asked questions which probe their liking for their teacher or the subject matter, enjoyment of their classmates, the perceived degree of threat in the class, or whether they would take more courses in that area.

Finding ways to aggregate multivariate outcomes so that many kinds of achievement and affective responses may be used to indicate the quality of classroom life for a child is a major research problem. As Berliner (1976) puts it ". . . multivariate outcome measures, simultaneously considering both achievement and affective outcomes [are] needed for research on teaching. If researchers in this area do not consider what is learned and what is felt about that learning, simultaneously, they will continue to fractionate school learning into pieces that do not resemble the students' view of reality" (p. 7).

Decision framework. Not only is the question of what outcomes should be examined quite complex, but also we must ask how to elicit the information we need. Three aspects of this question should be considered by researchers. First, what is the character of the decision to be made (or question to be answered)?

	Number systems	Geometry	Algebra
Computation			
Comprehension			
Application			
Analysis			

Figure 13. The content by process matrix used in NLSMA (Romberg & Wilson, 1969).

The answer involves both the kind of errors (Type I and II) one is willing to live with and whether the decision is irrevocable.

The second question is, What is the "unit" about which the decision is to be made? An answer to this question (individuals, groups, classes, school, materials, etc.) should dictate many methodological decisions in any research study.

The third question is, What measurement procedures and decision rules are to be used in the study? Answers to this question involve specifying the source, the scaling procedure, the reliability, and the validity of the measurement process. For example, in any educational setting there are potentially four types of information from which data can be collected. These are classroom observations, performance tests, work samples, and paper-and-pencil tests. Figure 14 shows how these are related. The distinction between overt process and visible product refers to whether the assessment takes into account how a task is accomplished or simply infers processes by examining a product. For processes actual observation is needed (Romberg, 1976b).

The decision rules to be followed are often decided with regard to what statistical tests will be used, assuming that the power of the statistical testing procedures has been decided upon.

Although student outcomes are indisputably the ultimate dependent variables in research on teacher behaviors, researchers

	Overt process	Visible product
Informal	Classroom observations	Work samples
Formal	Performance tests	Paper-and-pencil tests

Figure 14. Four sources of data.

still must question what outcomes are to be examined, how data is to be gathered, and how the data is to be interpreted.

Pupil Actions

The underlying principle of our model is that a pupil's activities are central to learning. Learning takes place in time. Students learn mathematics to the extent that they have the opportunity to learn and that they spend time actively learning: paying attention, studying, trying.

Teacher behaviors are directly related to the engaged learning time of students. Pupil engaged time, in our model, is the immediate dependent variable for teacher behavior. The basic proposition is: What teachers do directly influences the time a child is actively engaged in learning. This relationship is so simple and so obvious that it sounds naive, but somehow it has escaped extensive study.

"Student learning time" as an interim variable between teacher behaviors and pupil achievement has been considered before.[4] However, student time has been used only as an independent variable to predict certain student performance variables such as achievement test scores.[5] The practical importance of shifting engaged time from its role as one of many predictor variables to being the primary dependent variable for classroom studies cannot be underestimated. Three examples of how student learning time may be operationally determined are in the Beginning Teacher Evaluation Study (BTES) (Fisher et al., 1978), the IGE Evaluation Study (Webb & Romberg, 1979), and Coordinated Study #1 (Small, Romberg, & Carnahan, 1979). Descriptions of these studies follow.

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[4] For an overview of studies using "time" as a variable see Karweit (1976).

The Beginning Teacher Evaluation Study. The BTES staff defined the pupil variable[6] of their Academic Learning Time Model as follows: First, as an index of student classroom learning the teacher's allocated time for reading and mathematics instruction was used. Next, they estimated the number of minutes of the allocated time students were actually engaged in learning (as opposed to time spent waiting, in transition between tasks, or off-task). This time scale was further refined by adjusting engaged time for student success rate and task relevance, and then labeled "academic learning time" (ALT).

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[5] This relationship of engaged time to achievement was studied in BTES (See Fisher et al., 1978). Also see Borg (1979) for an analysis of that relationship).

[6] Each of the variables are operationally defined in terms of coded observed behaviors. Thus, the labels refer to codes rather than logical categories.

Success rate, intended to reflect how well the student understands the learning task, is a complex concept that warrants elaboration. If the task is very difficult and the student produces few correct responses, the activity will not produce much learning. On the other hand, the hypothesis suggests that if the student produces many correct responses on the task, more learning is occurring.

Success rate was assessed in BTES in three fairly broad categories. High success rate described situations where the student had both a good grasp of the task and made errors at about the chance level ("careless" errors). If a student did not understand the task and made correct responses at about chance level, the situation was labeled low success rate. Medium success rate is where the student has partial knowledge, and understands enough to produce some correct responses, but also commits errors. Only engaged time spent on high success rate tasks was included in the final measure. Task relevance was also considered in academic learning time to improve the prediction of achievement. Only those tasks which were measured by the achievement tests were considered.

Thus, academic learning time is time spent by a student engaged on a task in which few errors are produced, and where the task is directly relevant to an academic outcome. To complement

ALT a second pupil activity variable also was identified by the BTES staff: relevant, engaged time spent on tasks with a low success rate.

The primary procedure for gathering data on ALT was direct observation. A sample of students in each classroom was selected and both their actions and the related teacher actions were coded. Observations were gathered on several occasions during a year of instruction. Data on allocated time were taken from teacher logs. Data were collected in regular elementary school classrooms at both grade two and grade five.

The major findings relating to allocated time, engaged time, engagement at high success rate, engagement at low success rate, and academic learning time were:

1. The amount of time that teachers allocate to instruction in particular content areas is positively associated with learning in that content area.

2. The proportion of time that students are engaged with reading and mathematics materials is positively associated with academic achievement.

3. The proportion of time in reading or mathematics tasks that provided a high success rate for a student is positively associated with student achievement.

4. The proportion of time in reading or mathematics tasks that provided a low success rate for a student is negatively associated with student achievement.

5. Academic learning time is positively associated with student achievement.

In summary the findings indicate that if allocated time, engaged time, and success rate in school activities are changed, test scores reflecting student achievement will also change. Moreover, strong evidence suggests that academic learning time is an important predictor of student achievement.

The IGE Evaluation Project. The main purposes of Phase IV of the project are to determine the effectiveness of three curriculum programs in meeting their objectives, and to determine the relationship of pupil outcomes to instructional time and means of instruction. The three programs tested are Wisconsin Design for Reading Skill Development (WDRSD) (Otto, 1967), Developing Mathematical Processes (DMP) (Romberg, 1977), and the Pre-Reading Skills Program (PRS) (Venezky & Pittleman, 1977). Phase IV was restricted to investigating three groups of variables--pupil outcomes, instructional time, and means of instruction.

Student activities are summarized in terms of allocated, available, engaged, and nonengaged time. Student engagement is further classified as written, oral, or covert, and non-engagement is classified as nonacademic or interim activity, or simply off-task.

Teacher logs provided an indication of the time allocated for instruction for each content objective over the testing period. Teachers also maintained a log on students observed under the observation schedule. The observation system (Webb, 1978) was a modification of the system used in BTES (Marliave, Fisher, Filby, & Dishaw, 1977). Initially, six students were randomly selected in each class. These target students were observed using a time sampling procedure. All six target students were observed in sequence and their activity coded. This sequence took approximately 3 minutes. Thirty seconds were then allowed to record the teacher role and general activities in the classroom. The cycle was repeated during the time allocated for work on the curriculum program.

While a complete set of data for IGE (Phase IV) is not available at the time of writing the following findings are clear in the data:

1. The amount of time that teachers allocate to instruction in mathematics appears positively associated with student learning in mathematics. This trend is stronger for grade two students than grade five students.

2. There is insufficient data to warrant any conclusion about the relationship between engaged time and student learning.

3. With respect to engaged time, the optimum balance of self-paced to other activity and individual/small group/ large

group instruction is a delicate one which is not clearly resolved by the IGE data.

It does appear however that providing very large amounts of individual activity time (in this case over 80%) is not conducive to high pupil engagement. Notwithstanding this, where moderate amounts of individual activity is provided, a higher ratio of engaged/nonengaged time is produced than with other paced activities and large group instruction. These findings, though based on a limited amount of data, seem consistent with the findings of Good and Grouws (1977a) and the BTES study. Good and Grouws advocated teacher directed work for a substantial portion of each class period followed by independent practice by students, and BTES showed that whole class or group activity was more appropriate than independent work for grades two and five mathematics.

When students are not engaged during other paced activity or large group teaching, the greatest percentage of time is lost in waiting, either waiting for the teacher or other students. In self-paced or individual activity, interim time accounts for the greatest percentage of nonengaged time. This includes activities like sharpening pencils, turning in and passing out papers, and getting materials. Pair and small group arrangements produce very little nonengaged waiting and off-task behavior. However, the pair arrangement tends to create substantial nonengaged interim time.

4. With respect to the use of materials, children spend the greatest amount of time involved in paper-and-pencil activities. Manipulatives fall into the second highest category but are used more in grade two than grade five. Games are sparingly used and usage appears to depend on teacher preference rather than grade level or school.

The most significant result is that manipulatives and games do not produce high engaged/nonengaged ratios as might be expected in view of their high motivational value. In using paper-and-pencil activities, students waste appreciable amounts of time waiting for the teacher and other students. However, considerable time is also lost in getting materials and waiting for the teacher or other students when manipulatives and games are used. Hence the need for careful classroom management in using materials is an important consideration for the teacher.

Coordinated Mathematics Study #1. The intent of this study is to examine how first grade children acquire the skills needed to symbolically represent a variety of addition and subtraction problem situations, and how they solve these problems.

In the part of this study of major interest to this paper, the experimenters attempted to determine how content influences teacher behaviors during instruction, and in turn how these behaviors affect pupil outcomes. In particular, the extent of children's engagement in learning mathematics is examined. This procedure is based on the Romberg model (see Chapter I) which hypothesizes that "content segmentation and sequencing" and "content structuring" influence teacher planning, which in turn influences classroom organization, the allocation of instructional time, verbal interactions within the classroom, and eventually, pupil engaged time.

To test this model, data was gathered on the various components of the model in realistic settings. Those data were used to see how well the model fit the reality of classroom instruction as was observed in the field. To accomplish this, trained observers were present in each of eight classrooms while six initial addition and subtraction topics were being taught. Thus six periods of observation of two or three weeks in each class were spent recording information about classroom events.

The procedures used to collect data on means of instruction were similar to those used in Phase IV of the IGE Evaluation Project. Within each class a random sample of six students was identified and observed in a rotating sequence during each day of mathematics instruction. At the end of each minute of instruction (the moment of observation), the coder recorded information about the student and the teacher.

The coder observed whether the target student was present or absent; if present, the size of the group in which the student was working (alone, in a small group, or in a large group); whether the student was engaged or off-task; the topic of engagement (content or directions); the verbal interaction of the target student with others (whether speaking and to whom); and whether the activity was structured or unstructured. The coder also recorded teacher behavior in the following categories: teacher interaction (speaking with pupils, and if so, to how many); questions (if asked, whether high or low level); feedback (explaining content or directions, relating content to previous or future learning, outlining objectives or purpose, or summarizing content) and strategy change (reacting to pupil responses by an unplanned change of strategy). At the conclusion of the lesson, general information about the use of materials, teacher and pupil mobility, time allocation and variety of activities was also recorded. Measures were obtained for each class on number of days assigned to each topic, time the teacher intended to make available for the topic on each day, and the actual time devoted for a topic on each day. These measures were in addition to the measures of engaged time obtained from target observations, which were aggregated to estimate mean class times on the variables. Full details of the coding categories used in Coordinated Study #1 are described in Small, Romberg, and Carnahan, 1979.

In summary, the coding scheme was developed in an attempt to capture the content, teacher behaviors, and pupil actions in the model of mathematics instruction (Romberg, 1978a) described earlier. Data were gathered based on observations made during the time-sampling sequences. For Coordinated Mathematics Study #1, data were collected during the period January through December, 1979, in eight grade one classes. While the complete data for this study are not yet available, the initial tabulations show:

1. Great variability exists between classes in the amount of time teachers assign and actually devote to mathematics topics. This variation seems to be more related to teacher characteristics than the characteristics of the mathematical content, since teachers tend to be consistently high or low (compared to each other) in the amount of time allotted to mathematical topics.

2. The variability in engaged time spent on mathematical content reflects a similar picture to that described for allocated time, although compensating for engaged time spent on directions reduces this variation.

3. Large group and individual student activity predominate in the classes, indicating that teachers feel more comfortable with these modes than small group activity. Classes with low engagement levels tend to show excessive amounts of either large group or individual activity, although no clear pattern emerges for classes with high engagement levels.

4. There is no tendency for teachers or students to vary interaction patterns across the three topics. Teachers spend a high percentage of their time in interactions but students spend at least 60% of their time not interacting with anyone. Students could attain higher levels of interaction by interacting more frequently with other students. The fact that teachers spend a very small percentage of their time listening may have important consequences for monitoring and evaluation.

5. Negligible amounts of time are spent by teachers on summarizing and outlining objectives, and very small amounts of time are spent relating present content to past or future content. This finding is unexpected in view of the stress placed on these actions in the literature.

6. When teaching questions are asked, low-level questions predominate; in fact, high-level questions are almost completely absent. While it is difficult to determine an appropriate level of questioning in classroom instruction, the overall figure of 20% revealed in this data appears to be low.

7. As the classes continue through the sequence of topics the following trends in instructional practices are apparent:

   a. the percentage of time spent in individual and small group activity increases while the percentage of time spent in large group activity decreases;

b. the percentage of time the teacher devotes to both explanation of content and directions *decreases*; and

c. the percentage of time the teacher devotes to all levels of questioning *increases*.

All these changes are accompanied by an increase in engaged time (for the aggregate of eight classes). This effect is consistent with the relationships postulated in the Romberg model. A possible interpretation is that teachers adopt more flexible strategies as they gain confidence with the material. An alternative but not inconsistent explanation is that the characteristics of the material and mathematical content in the three topics require different instructional strategies. Either alternative or a combination of both would be consistent with the Romberg model.

Summary and Conclusions

These three studies demonstrate that measuring the time students are engaged in learning captures an important aspect of pupil classroom behavior. Clearly, however, "engaged time" by itself is not meaningful; the nature of that engaged time--on relevant tasks, on appropriate levels of difficulty, and the like--must also be determined. In particular three aspects of engaged time which need to be considered are content coverage, the episodic nature of instruction, and interactive engagement.

Content coverage was included in all three studies. The BTES staff considered content relevance, and both the IGE Evaluation Project and Coordinated Study #1 controlled content coverage through the use of DMP in the classes. Neither approach is completely adequate. The distinctions between the intended and actual coverage, whether the activities are pertinent both to the content and to the learner, and what is tested are not clear. We must ascertain, for instance, whether students are engaged in activities that are reasonable and intentional. We are not yet able to make this kind of judgement.

Lessons and units have an episodic structure. Like a story, a unit must have a start, a development, a climax, and a summary. The type of activity and the character of the pupil's engagement should be appropriate to the development of the unit. We are still unable to capture this feature of engagement.

Finally, to be engaged means to be interacting with ideas. The typology of those interactions is not well developed. Although teacher-pupil interactions have been examined, peer interactions and their dynamics are missing in our analysis.

In conclusion, the problems surrounding both the variety of pupil outcomes and the notion of engaged time as an indicator of pupil activity should be apparent. Researchers must be aware of these problems and select outcomes and definitions of engagement that illuminate the particular issues they intend to study.

VII

TEACHER AND PUPIL BACKGROUND

by

Marian S. Small

Teacher Background

We recognize that certain personal characteristics of individual teachers affect instructional behavior both directly and through the choice of the content and techniques used to motivate and plan. In our model of instruction, we have included a label for teacher characteristics, although we are not using measures of these to predict instructional variability or pupil outcomes at this time. In part this is a recognition of the fact that to a large extent, the "average" teacher produces similar results whether in Buffalo or Honolulu, whether male or female, whether cheerful or stern. Except with measures of pupil outcomes, we do not have tools to describe what makes teachers exceptionally good or poor. For the most part, teachers engage in similar teaching strategies for a given age level of students and given subject matter area. We wish to study these strategies rather than what causes them. However, a number of variables reflecting teacher characteristics, ranging from measures of intellectual ability and job satisfaction to measures of humanistic attitude and flamboyance, should be mentioned briefly.

Ryans (1963) summarized research on factors contributing to instructor behavior from studies reported between 1958 and 1963. He distinguished six categories of internal inputs to teacher information processing, four categories of external inputs, and four categories of teacher information processing, all contributing to teacher classroom and planning behavior. Among the teacher characteristics listed are: physiological measures; general human capability; academic ability; a variety of typical behavior styles such as enthusiasm, organization, warmth, dominance, and flexibility; a variety of typical affective sets such as academic orientation, professionalism, emotional adjustment, confidence, and permissiveness; and knowledge of content and techniques. In listing external inputs to teacher information processing, Ryans acknowledged the influence of student and school characteristics on the manifestation of teacher behaviors. The four types of information processing variables listed relate to problem-solving abilities, classes of logical operations, teacher feedback effects, and actual processing via filtering, decision making, channeling, and so on.

In an earlier work based on a 6-year study of teachers, Ryans (1960) reported on differences among teachers in observable behaviors.

Three major clusters of observable behaviors were identified. The first was a measure X along a dimension with one extreme being understanding and friendly and the other aloof, egocentric, and restricted. The second was a measure Y along a dimension with one extreme being responsible, businesslike, and systematic and the other evading, unplanned, and slipshod. The third was a measure Z along a dimension with one extreme being stimulating, imaginative, and enthusiastic and the other dull and routine. These factors were culled from a greater number of ratings including measures of such characteristics as levels of poise, optimism, and flexibility. All three factors, but particularly Y, appeared to be fairly stable over a 14-day period and the factors were substantially intercorrelated, particularly at the elementary level.

Ryans reported three major factors relating to teacher viewpoints toward the school. The first measured stress on an academic-centered program and included data on the teacher's perception of the desirability of homework and level of standards. The second measured the rigidity of the program, including the teacher's freedom to modify courses. The third measured the extent of teacher-directed learning and the traditional nature of the subject matter areas covered. Later these were combined into a single dimension, which might be termed level of permissiveness.

Other data used to analyze differences between teachers included age, sex, recency of college training, marital status, grade level of pupils, activities during childhood, level of experience, and size of school.

Brophy and Good (1970) classified teachers into three types--the proactive, the reactive, and the overreactive. The proactive teacher establishes and maintains the initiative in structuring classroom interactions, using his or her expectations as a tool. The reactive teacher adjusts his or her behaviors according to actual pupil behaviors, and the overreactive teacher streses differential pupil expectations. Although the difference in use of expectations about pupils is an actual behavior rather than an underlying teacher characteristic, the propensity of an individual toward one type of behavior is probably rooted in the teacher's attitudes about the potential for student change (distinguishing the overreactive teacher from the others) and the teacher's ability to be spontaneous and flexible (distinguishing the reactive teacher from the others).

In an evaluation of the extent of implementation and resulting pupil and teacher outcomes in schools which adopted the IGE model of schooling, Romberg (1978a) proposed a model which included several teacher characteristics as contributing to a prediction of pupil outcomes. Included are data on staff background, such as extent of professional preparation and commitment, as well as teacher assumptions about learning, knowledge, and schooling and their consonance with basic IGE assumptions. These two variables might be expected to underlie differing classroom behavior. Also measured is the teacher's level of job satisfaction. Ekstrom (1976) reported that teachers with low aspirations were more likely to have pupils working independently of them.

Leiter (1974) observed teachers of young children and compared warm, motherly types with those strongly oriented academically. Leiter believes that these two types of teachers will explain performance differently and thus interact differently with their pupils. For example, the motherly type might need to be more indispensable to the pupils and might discourage peer interaction and pupil independence.

Ebmeier and Good (in press) sought to identify teacher types so they could examine the interaction of student types with teacher types in producing effective pupil learning in elementary school mathematics. They developed an inventory with seven subscales: need for personal control, need for contextual stability, expression of belief in individualizing instruction for children, expression of belief in using abstract and unfamiliar teaching materials, degree of security in teaching math, teaching experience, and level of education in mathematics. From these, cluster analysis was used to distinguish four teacher types: the less experienced/less educated, the experienced/unsure, the educated/secure, and those believing in individualization of instruction. These types did interact with pupil types differently in affecting pupil achievement in mathematics.

Clearly, many teacher characteristics have been identified as possible influences on teacher behavior and more could be named. At this point, we believe our major task is to observe the manifestations of teacher characteristics in teacher behaviors to predict instructional variability and pupil outcomes. At some later time, we might choose some of the other descriptors we have listed to make our model more complete. Although intelligence, information processing capacity, and so on may be relevant, we wish to begin with measures having a more direct effect on instruction, such as those examined by the IGE evaluation staff (Romberg, 1978a). Their variables included teacher beliefs, in particular, the teacher's attitude to the discipline being taught and more general beliefs about knowledge, learning, and schooling.

Pupil Background

In our model of instruction we consider the role of pupil characteristics in affecting teacher behaviors, pupil pursuits, and pupil outcomes. The pupil outcome we attempt to predict is pupil engagement rather than achievement. Engagement is positively correlated with achievement (Fisher et al., 1978), but measures of engagement are not likely to be affected by pupil ability level to nearly the same extent as are measures of achievement. Thus there are, in some sense, more accurate measures of the teacher's direct effect on learning. Of course, pupil characteristics play a part in predicting teacher actions and pupil engagement. Although we do not attempt at this time to explain how pupil characteristics affect other components in our model, we briefly examine pupil characteristics other researchers have postulated to be relevant to teacher behaviors and pupil outcomes. We examine separately biological and environmental factors, aptitude and achievement factors, developmental factors, learning styles, and factors related to personality. More detail about these factors will be described in a future theoretical paper.

Several of the important studies done in process-product research in the classroom have reported levels of socioeconomic status (SES) when describing their subjects. A few studies went beyond this. Brophy and Evertson (1974) analyzed data from their study of instruction in grades two and three separately for high SES and low SES classes and found many teacher patterns of behavior effective in one setting and not the other. For example, they (1977) reported that low SES pupils needed to learn material in smaller chunks with more repetition and practice, while high SES pupils performed better when challenged. They found that teacher questions should be easier for low SES pupils than for high SES pupils. Teacher praise was important for low SES pupils, but not for high SES pupils. Immediate feedback was best for low SES pupils, but delayed feedback for high SES pupils. They also discovered that the number of incorrect pupil responses was positively associated with achievement gains for high SES students, but was negatively associated with gains for low SES students.

Good, Ebmeier, and Beckerman (1978) also analyzed data separately for high and low SES classes. They learned that praise was negatively related to achievement in high SES classes, but positively related in low SES classes and that a relaxed climate was more important for low SES classes. They also found differences in the effectiveness of teacher-initiation of contacts and of continued teacher probing in the event of an incorrect response. The latter result was in direct conflict with the Brophy and Evertson data. The authors believed that SES did not appear to be as important a variable in their study as in the Brophy and Evertson study because they concentrated exclusively on mathematics and fourth graders, rather than on younger children. In any case, Good et al. suggested that SES should be considered in determining which patterns of teacher behavior are likely to be effective.

Good, Sikes, and Brophy (1973) reported a study on the effects of teacher and student sex on classroom interaction. The data were collected at the seventh- and eighth-grade levels in 16 mathematics and social studies classes over a 2-week period.

Student sex was a significant variable for 20 out of 62 dependent measures of classroom interaction. In summary, boys initiated more comments and questions, were asked more process questions, and were involved in more total contacts with the teacher, both positive and negative, both private and public, than girls. Achievement interacted with sex to produce further differential effects. The high achieving boys seemed to get the most positive interaction in the classroom and the low achieving boys the most negative. We are concerned primarily with the elementary school level, but sex differences found at upper grade levels would show up with younger children as well. We would expect differences in interaction patterns, teacher choice of activities, and organization of students. Indirectly pupil sex may influence pupil personality characteristics which would, in turn, affect pupil behaviors. Fennema and Sherman (1977) are examining the influence of sex on achievement and other relevant mediating variables in mathematics.

An important set of pupil measures to consider in our model relate to achievement and ability levels. We can reasonably expect that prior achievement and aptitude scores would be predictive of pupil and teacher actions. As was mentioned earlier, Good et al. (1973) considered achievement differences based on teacher ranking in addition to sex differences in studying classroom interaction patterns, and found that differences due to achievement were significant. High achieving students received more positive teacher feedback, initiated more teacher contacts, received more questions, and were more actively involved in the classroom communications network than low achieving students.

Anderson and Scott (1978) studied the effects of various classroom organizations on student time spent on task for differing levels of scholastic aptitude and academic self-concept. Although they studied students in grades nine through twelve, again, we suspect the data are relevant to elementary grades. A total of 100 students were observed in humanities and social science classes. Students with low aptitude as measured by the verbal subtest of the Lorge-Thorndike Intelligence Test and low academic self-concepts as measured by the Scott Academic Self-Concept Scale were most affected by organizational environment. Although all students observed were off-task more in a small group setting than in whole class discourse or seatwork, the increasing off-task behavior was particularly evident for the low aptitude and low self-concept students. Their average task involvement was 63% during classroom discourse and 50% during seatwork, but only 9% during small group work. Average time-on-task percentages for high aptitude, high self-concept students fell from 61% during classroom discourse and 56% during seatwork to 29% during small group work. Changes in percentages of off-task behavior were more modest for low aptitude, high self-concept and for high aptitude, low self-concept students when classroom organization varied. High aptitude students were on task most when audiovisual materials were being used in a whole class setting. This was not the case for low aptitude students.

In his model of school learning, Carroll (1963) suggests that pupil aptitude for the specific instructional task at hand and ability to understand instructions are predictive of the time needed in learning. Our model suggests that information about such aptitudes and abilities could be used by the teacher when allocating instructional time. Aptitude for the task may depend not only on prior learning, but also on personal characteristics. These were not further elaborated by Carroll in his original paper. He did explain that the ability to understand instructions is a combination of general intelligence and verbal ability and is an ability particularly important when the learner is left to his or her own devices to proceed on a task.

This ability, to understand instructions, I think, is related to what Doyle (1978) refers to as an awareness of the cues of the classroom; the ability to distinguish between significant and irrelevant information. Doyle extends this concept and suggests that pupils who vary in their ability to use cues vary in their ability to accurately monitor and interpret teacher behavior. As an example of using cues, he points out that not all potentially correct answers are acceptable to a particular teacher at a certain time and that the student must learn to identify situational indicators.

In summary, we find many sources suggesting that pupil aptitudes and abilities should be taken into account when analyzing instruction. Prior achievement and more general ability affect engagement levels in various organizational settings, affect interaction patterns, and affect ability to proceed without help. We know that teachers often use information about achievement to plan activities and groupings. Therefore, some account of these pupil characteristics is essential for a thorough model of instruction.

The work of Piaget (Copeland, 1976) and his followers has centered on the relevance of the child's developmental stage to the ability to understand certain ideas. A summary of research relevant to mathematics education in the area of cognitive development can be found in Carpenter's (in press) chapter in a new publication by the National Council of Teachers of Mathematics. We are interested in how pupil developmental level influences teacher planning of instruction.

Case (1975) suggested that instruction must be geared to the child's information coordinating capacity and to the extent of his or her field dependence. These measures are presumed to vary with stage of development. He established principles for planning instruction, recommending that the teacher design step-by-step strategies dealing not only with the particular concept to be taught, but any incorrect strategies children use during instruction on that concept (Case, 1978). The teacher's awareness of pupils' developmental levels goes beyond merely choosing content appropriate for a particular child. It involves analyzing each child's probable behavior and developing an instructional plan for each child. We believe that varying developmental levels of children must be considered when building a complete model of pedagogy.

Differences in the cognitive style of learners also have an important bearing on the effectiveness of different learning environments. Psychologists and educators use the term cognitive style to describe how people acquire and process information. Nelson (1973) reported on two systems of categorizing cognitive style. She cited one group who described eight, not necessarily disjoint, types of learners. The incremental learner learns best when taught in small, steady chunks. The intuitive learner makes guesses based on cues and is less systematic than his or her incremental peer. The sensory specialist learns mainly from one sense, where the sensory generalist uses all senses. The emotionally involved learner thrives in a warm, emotive climate, while the emotionally neutral learner prefers a more business-like environment. The explicitly structured learner prefers a more rigid environment than the open-ended structure learner. This type of information about personal style would allow the teacher to plan the right sort of organizational and interactive environment for each student.

The more traditional route to describing cognitive styles differentiates among students who level as opposed to sharpen, who are reflective as opposed to impulsive, who are field dependent as opposed to field independent, who focus as opposed to scan, and who excercise constricted control as opposed to flexible control. Standard tests are available to measure these traits. Leveling involves blurring memory differences to assist assimilation as opposed to maintaining sharp distinctions between items learned. Teachers could provide different structuring comments for these learners. Reflective pupils need time to mull over questions or comments before acting. Teachers could provide additional time for these pupils. Field dependent children are apt to assume the context is relevant when learning new material.

In mathematics, where the abstraction must apply to many contexts, this can be minimized by providing multiple physical embodiments of concepts. Thus, learning style of pupils is relevant to our model.

Various social, cultural, and personality characteristics of pupils should be considered when predicting teacher decision making and pupil pursuits. Among those examined by other researchers have been pupil anxiety, dogmatism, introversion, dependence and passivity, conformity, perseverance in learning, preference for information sources or structure, academic self-concept, and general level of socioemotional development. Several of these characteristics are discussed in the following paragraphs.

Rich and Bush (1978) studied the effect of congruence of teacher and student characteristics in grades four, five, and six, over a 20-day instructional period. A total of 20 teachers and 94 students were involved. Teachers were categorized as direct or indirect based on a Flanders analysis of their verbal behavior. Student social-emotional development (SED) ratings were based on four sources of data: a teacher ranking of the pupil as to level of independence, leadership, participation, and creativity; a peer sociogram; and two student self-reports. As one of the dependent measures, Rich and Bush observed pupil time on task.

They found that high SED students were more attentive to their tasks with indirect teachers whereas low SED students were more attentive with direct teachers. Achievement differences were also significant.

Peterson (1977) explored the effects of student anxiety and teacher behavior on achievement at the grade nine level. Four treatments varied in the amount of teacher structuring: stating or eliciting objectives, providing a review of previous work, signaling transitions, etc. (high or low), and the level of pupil participation (high or low). She learned that the effects of anxiety interact with those of ability. High-anxious students of high ability and low-anxious students of low ability performed worst in a low structuring, low participation situation. High-anxious students of low ability and low anxious students of high ability performed best in that condition. Therefore, both interactive and organizational environments should be planned with student anxiety measures in mind.

Although Helton and Oakland (1977) studied elementary school teachers' attitudinal responses to pupil characteristics, their work is relevant to our model. Since teacher attitudes to pupils differ, their patterns of behavior toward those students will differ (Brophy & Good, 1970). Helton and Oakland found that teachers react positively toward rigid-conforming-orderly and passive-dependent-acquiescent pupils. They feel negatively toward more flexible-nonconforming-untidy and active-independent-assertive children. Thus, we would expect different amounts of contact and feedback to be provided to these two different types of pupils. Ebmeier and Good (in press) also classified students as dependent or independent. They found that dependent pupils perform best with experienced but insecure teachers, and that independent pupils can operate efficiently in a wide range of situations.

Carroll (1963) stresses the importance of pupil perserverance in learning. This helps predict the amount of time a student is willing to spend to accomplish a task, and, therefore, the degree of his or her learning. He suggests that perseverance is a function of motivation or other emotional variables, but is often affected by quality of instruction. We know that some students "give up" more easily than others, but this is more prevalent in some classrooms than others. Teachers should consider pupil perseverance in planning motivational strategies.

Good and Power (1976) observed many classrooms and differentiated between four types of students: the successful, the social, the dependent, and the alienated student. They acknowledge that other categories of pupils are possible, but these four are found consistently among pupils of several different countries.

The four types of students have different needs. Successful students enjoy long and challenging assignments; social students need more opportunity for public performance and would not enjoy working alone on a long assignment. Dependent and alienated pupils require large amounts of teacher contact. They spend a great deal of time waiting for teacher help or approval. To optimize outcomes, Good and Power predict social students should be involved in small group work with no teacher interaction 40% of the time; they should be involved individually with the teacher only 2% of the time. At the other extreme, dependent children should be involved in unsupervised small group work only 5% of the time, and 25% of the time should be spent individually with the teacher. These figures have no empirical support, but are only guesses. Although more work is necessary to elaborate this model, Good and Power have an interesting idea.

As we indicated earlier, we have not specified the measures of teacher and pupil characteristics we believe to be most important in predicting teacher behaviors and pupil outcomes, although we have made suggestions. We are concentrating now on using information about content to predict classroom events and average outcomes. After we have obtained general data, we wish to specify the effects of different types of pupils on different types of teachers. The next theoretical paper will concentrate on how teachers can use information about pupil characteristics to advantage in designing instruction.

VIII

SUMMARY

by

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and Richard Carnahan

In this chapter we present a revised model of pedagogy based upon our literature review. We will define elements of the model and discuss their relationships. We end by reflecting on the modeling process, on our conclusions, and on ideas that remain to be developed.

A Revised Model of Pedagogy

Our original model (Figure 8 in Chapter I) had 14 variables organized under three general headings: content, means of instruction, and outcomes. In our revised model we propose four categories: the three original categories and a background category. The means of instruction category originally had four subcategories: motivation, planning, direct instruction, and pupil pursuits. In the new model three subdivisions are made: planning, classroom events, and pupil pursuits. Motivation was dropped not because we found it unimportant but because motivational elements are involved both in planning and in classroom events. The term classroom events was chosen as a replacement for direct instruction primarily because direct instruction has come to indicate a particular style of instruction (cf. Rosenshine, 1978) rather than a subcategory of pedagogic behaviors. Thus, direct instruction is now a label for a particular pattern of classroom events.

Next, from our review we have identified 19 variables (instead of 14) and we distinguish between two types of variables: specific and general. Specific variables are well described, refer to actions, and can be scaled. General variables are not well defined. In specific studies, the aspects of a general variable of interest would need to be described before scaling could proceed for each. The relationships between these general variables and other variables are tenuous, and indeed may vary from study to study.

The Background Elements

Two general variables have been identified for inclusion in this new but necessary category. The variables are:

TB = Teacher Background. This general variable refers to characteristics the teacher brings to the instructional scene. Both personal characteristics and those acquired through training may be included.

PB = Pupil Background. In a similar manner this general variable refers to characteristics the pupil brings to the instructional scene. It too includes both personal characteristics and skills previously acquired.

The Content Elements

Three specific elements have been identified in this category. In the original model two content elements, content unit structure (CUS) and content segmentation and sequencing, were specified. We have divided the original content unit structure element into two elements, one to reflect the "goals" and one the "richness" of a particular content unit. From the review of content-related questions (Chapter II) we have decided that the three-part content unit structure element contains eight subelements: concreteness, diversity of approach, applications, explorability, importance and clarity of objectives, algorithmic nature of teaching, encouragement of pupil discussion, and intended outcomes. Thus, the components of the content category are as follows:

CG = Content Goals. This element is derived by considering:

a. Importance and Clarity of Objectives

Content is categorized by activity according to whether it is judged by the teacher to be of little importance, moderate importance, or great importance to pupils. The materials are examined and the teacher questioned to see if the activity clearly meets its objectives.

b. Algorithmic Nature of Teaching

Content is judged by activity according to whether the teacher is expected to teach it in an algorithmic, routinized manner and whether this is actually done.

c. Intended Outcome

Content is categorized by activity as to its intended outcome, be it maintenance of previously learned material, acquisition of new material, or preparation for later work. The point of view of the curriculum designer and the point of view of the teacher are taken into account.

CR = Content Richness. This element is derived by considering:

a. Concreteness

Content is categorized by activity, both in terms of opportunities to use manipulatives or play games in learning it, and the actual use of these items in instruction.

b. Diversity of Approach

Content is categorized based on topic objectives in terms of whether more than one basic approach is made available for instruction, and whether more than one basic approach is actually used by the teacher. The extent of repetition of each approach is also measured. On a broader basis, a program is analyzed to determine whether it attempts to structure its topics by using unifying cognitive themes.

c. Applications

Content is categorized by topic and activity according to whether a variety of applications within the scope of the students' abilities exists, and whether the pupils actually meet this variety. The applications themselves are examined as to whether they are primarily artificial ones or realistic, whether they are set into games, and whether they are designed primarily to practice or are placed in units designed to teach other content.

d. Explorability

Content is categorized by topic according to whether a number of student investigations of the material are feasible and whether such investigations are actually assigned. A distinction is made between highly structured explorations and more open investigations.

e. Encouragement of Pupil Discussion

Content is judged by activity to determine whether pupils are encouraged to discuss content with one another or with the teacher. This type of discussion is in contrast to simple responses to direct teacher questions.

CSS = Content Segmentation and Sequencing. This element is derived by considering:

a. Hierarchical Nature

Content is categorized by topic according to whether it has a critical set of curriculum prerequisites essential for its comprehension, and whether this is taken into account in instruction by the materials and by the teacher. Also judged is whether the activities included in a topic build in a systematic way and whether the teacher makes reference to relevant prior work in instruction.

b. Content Segmentation

Content is categorized by activity according to whether the activity is written cohesively, with an introduction, development, and conclusion, and whether it is taught that way.

c. Flexibility of Sequencing

Activities within topics and topics within programs are examined to see if alternative sequencing suggestions are provided to the teacher.

From the descriptions of these variables it should be clear that each includes both the features implied in the curriculum materials (what could be reasonably expected or anticipated), and what is actually done in the school. Thus, to scale these variables three sources of information must be used--data gathered through an investigation of the curriculum materials, data from interviews with teachers, and data from classroom observations.

The Planning Elements

The planning subcategory of the original model contained elements, information (a source for planning), and informed decision making. From our review of literature it became apparent that these elements were unsatisfactory. We now propose six variables: three deal with the information, expectations, and perceptions teachers have about instruction and how these ideas are used in planning; three deal with the details of the planning process and its product as perceived by the teacher. The variables are:

IP = Information about Pupils. This element is derived from the student background information which is available to the teacher and includes:

- a. a record of prior achievement;
- b. a judgment of the pupils' persistence or willingness to attend to a task; and
- c. a judgment of the pupils' independence.

IC = Information about Content. This element is derived from the information available to the teacher about the content area being taught and includes:

- a. specific information about the content goals of the unit;
- b. knowledge of how the unit goals are related to other goals and their importance in that relationship; and

c. an understanding of the role of review and preparatory activities in content sequences.

PE = Perceived Ease of Instruction. This element is derived from information about the teacher's perception of the ease of instruction for particular activities and includes:

a. perception of ease of student management for particular activities;

b. perception of ease of preparation for each activity; and

c. perception of time needed by students to complete activities.

PP = Pupil Planning. This element refers to the specific instructional planning the teacher does which concentrates on students in the class.

PC = Planning Content. This element refers to the instructional planning the teacher does which concentrates on the content to be taught.

PS = Planning Specificity. This element refers to how specific or detailed the teacher plans are.

These six planning variables include availability of information (such as from files of pupil records), prior knowledge of both pupils and content, teacher expectations, and the actual plans teachers make. Thus, to scale these variables information must be collected from an examination of work samples (the unit and lesson plans of teachers), from interviews of teachers, and from the records available to teachers.

The Classroom Events Elements

This newly labeled subcategory of means of instruction also contains six elements. The subcategory, called Direct Instruction, had four elements: structuring comments, organizational environment, interactual environment, and allocated time. The notions behind those variables have been retained, but reorganized into three elements which were derived from the literature review. The variables are:

MOT = Motivation. This element refers to the overall evidence of student motivation observable in the classroom. It includes strategies the teacher may use based on both available information about students and on information about content.

ROE = Richness of the Organizational Environment. This element refers to:

a. the variety of learning activities in a given lesson and over the course of a topic;

b. the grouping (large, small, or an individual) to which each student observed is assigned, and teacher criteria for determining grouping;

c. the extent and appropriateness of the use of physical materials; and

d. the levels of student and teacher mobility.

IOE = Independence of the Organizational Environment. This element refers to:

a. whether the student is engaged in a structured activity;

b. whether an activity is taught algorithmically where the teacher attempts to control the pupils' thinking processes, and the appropriateness of this procedure for a given objective;

c. the timing, amounts, and appropriateness of teacher-directed and independent work; and

d. the extent of teacher monitoring of independent work.

IE = Interactive Environment. This is the key element in describing classroom events. After lengthy discussions we have chosen to leave IE as a single variable although it contains five different aspects, each of which could be considered an important variable in its own right. The five aspects are verbal interactions, structuring comments, soliciting, reacting, and explaining.

Verbal interactions include interactions of students in terms of:

1. *direction*, that is who is speaking to whom; and
2. the *other participants*--teacher, student, or other adult.

For the teacher, we include verbal interactions in terms of:

1. *direction*, whether the teacher is speaking or listening;
2. the *size of the group* (*small*, *large*, or an *individual*) the teacher speaks to; and
3. whether the verbalization is a *question*.

For both teacher and pupils, we include whether the *interaction* is *regarding* mathematics *content*, *directions* related to that content, or *neither*. We also record whether interactions are *public* or *private*.

Structuring comments we believe are important in predicting pupil behaviors are those:

1. *relating* work to *past* or *future* learning;
2. *outlining objectives* of an activity; and
3. *summarizing* or reviewing content.

We believe their effects to be mediated by pupil perception of these types of statements.

The third aspect contained in the IE element is soliciting. Teachers vary in the amount of questioning they do and the types of questions they ask. We have included three main types of teacher questions:

1. low-order questions;
2. high-order questions; and
3. management questions directly related to content.

The last type of question is included to maintain a distinction between solicitations regarding substantive matters and those regarding directions.

Reacting moves are teacher behaviors which occur after a pupil response From our review of literature we believe the following occurrences are important:

1. the informativeness of feedback as either high information or low information;
2. the absence of feedback when it is expected;
3. the sign of feedback as either positive, negative, or neutral; and
4. teacher strategy changes.

Explaining, the fifth aspect of the IE element, includes explaining of content or directions, not structuring, soliciting, or reacting. The teacher talks and the students listen. Much classroom talk falls in this category. We believe instances in which the teacher:

1. *explains content*; or
2. *explains directions* are importnat.

We use the word *explain* here broadly to imply any teacher exposition. Also, the *clarity* of explanation must be considered.

AT = Actual Learning Time. This element refers to the time allowed for learning or opportunity to learn. A teacher may allocate time differently for various types of pupils, classes, or content of different levels of importance or complexity. Therefore, we suggest that only actual learning time as a subset of available (or allocated) time be used as a predictor of pupil activities.

PI = Pacing of Instruction. This element refers to the teacher's establishment of a pace for the class (and groups) to cover materials. Thus, the actual time per unit of instruction is used as an index of pace.

From the descriptions of these six variables on classroom events we expect to capture the salient features of what is involved in the complex teacher-student-content interactions which occur in classrooms. To scale all these variables, observational data based on time samples appear to be an appropriate procedure.

Pupil Pursuits

One general variable has been identified for inclusion in this category. The variable is:

ET = Engaged Time. This variable refers to the amount of time each pupil is actively engaged in learning content material.

This has been left as a general variable since this description may be qualified in terms of task relevance, time needed, and so on. In any particular study an operational definition which fits the objectives of that study must be developed.

Outcomes

One general variable has also been identified for inclusion in this category. The problem here is specifying which set of outcomes one is interested in examining. For generality the variable is:

SO = Student Outcomes. This element refers to all the possible student outcomes one could identify which are influenced by schooling.

Relationships Between Elements

For these 19 variables we are willing to posit 31 specific relationships as follows.

1. PB → SO Prior pupil achievement (attitude and so on) influences later student outcomes (achievement, outcomes, and so on).
2. PB → IP Actual pupil background should influence the information that is available about pupils.
3. TB → IC Teacher content preparation should influence the teacher's understanding of the information about content.
4. TB → PE The teacher's experience should influence perceptions of management, preparation, and pacing.
5. TB → IE The teacher's experience should influence the variety of teacher behaviors involved in interacting with pupils.
6. CG ↔ CSS (a) If a teacher sees a topic as particularly important, then attention is given to developing an appropriate sequence.

   (b) Knowing that a pupil has prerequisites or needs prerequisites should affect the intended outcome.

7. CSS → IP If records of mastery of prerequisites are kept, then information on pupils is available.

8. CSS → PS Amount of segmentation and sequencing determines the amount of specific planning needed.

9. CSS → IC The way content is sequenced provides information about content.

10. CR → IC The richness of content is certainly information about content.

11. CR → PE The richness of content should influence (probably inversely) the perceived ease of instruction.

12. CG → IC The objectives of a unit are certainly information about content.

13. CG → PE The importance of a unit should influence the teacher's perceptions of how much effort needs to be expended for the unit.

14. IP → MOT Teachers may use information about students as a basis of a motivational strategy.

15. IP → PP Student background information available to the teacher should directly influence the instructional planning done by the teacher with regard to those students.

16. IC → PC The teacher's knowledge of content should, in part, determine instructional planning which deals with the content to be taught.

17. PE → PP Management expectations should influence planning for students.

18. PE → PI Perceived pace should influence actual pace of instruction.

19. PP → MOT Planning done with students in mind should influence particular motivational procedures used in the classroom.

20. PP → IOE Planning done with students in mind should directly influence the level of student independence which is operative in the classroom.

21. PS → IE Specificity of teacher planning (e.g., use of specific examples, explanations, questions, and so on) should influence the interactive environment of the classroom.

22. PC → MOT Planning done with content in mind should influence the choice of motivational procedures used in classrooms.

23. PC → ROE Planning for content will influence the richness of the organizational environment in terms of variety of activities and procedures used.

24. MOT → IOE Motivational strategies used should directly influence the level of student independence in the classroom.

25. IOE → IE If children work independently, they do not interact very often. More feedback is given to individuals than to groups.

26. IOE → PT If teachers instruct large groups, the pace is more homogeneous.

27. ROE → IE In a rich environment we expect more structuring comments, more pupil talk, more direction giving as activities change or manipulatives are explained, and more content talk.

28. IE → ET The quality of the teacher talk and the level of peer interaction affect pupil ability to understand tasks and be engaged. If teachers talk too much, children cannot work.

29. AT → P Pacing is a subset of actual learning time.

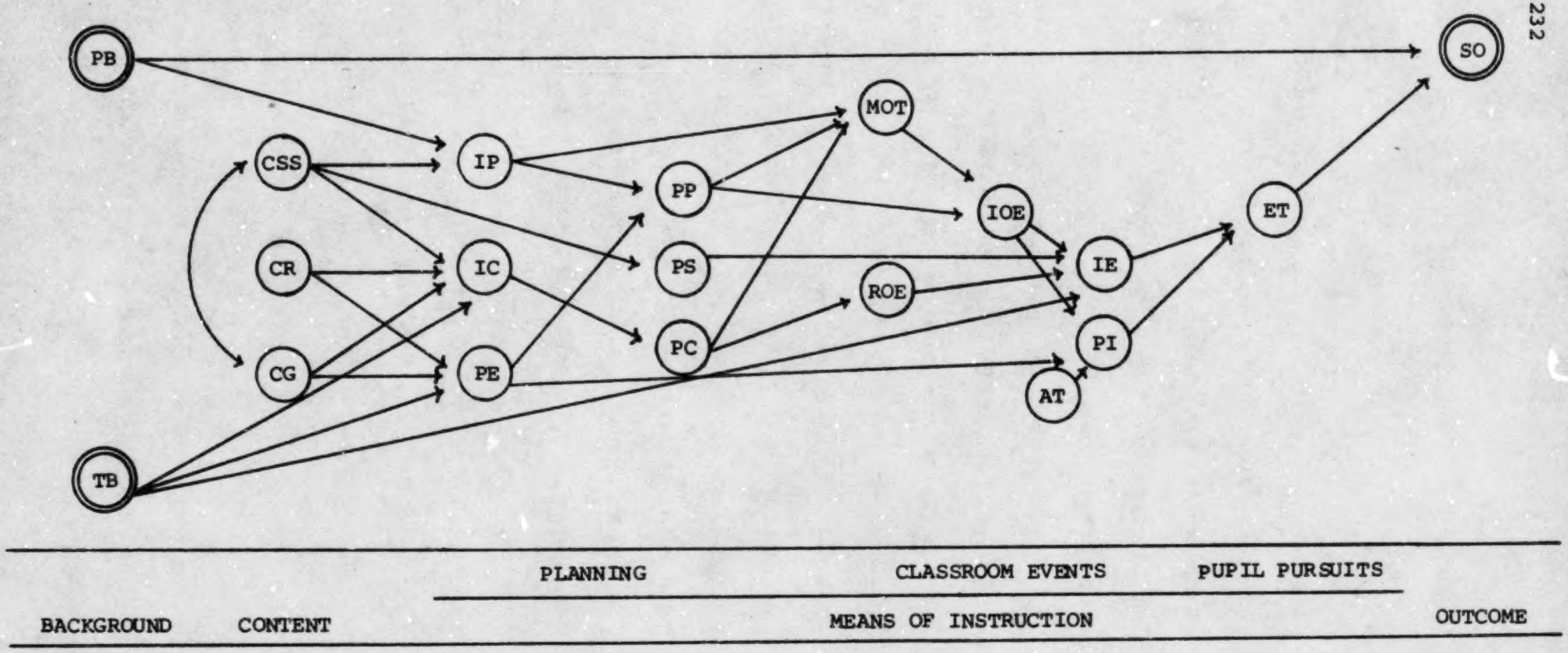
30. P → ET Engaged time is clearly influenced by pace of instruction.

31. ET → SO What pupils do should influence their outcomes.

A summary diagram of the 19 variables and their relationships is shown in Figure 15.

Reflections

This revised model of pedagogy, we believe, provides researchers a set of constructs which can be used as a starting point for the


PB
SO
MOT
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IP
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IOE
ET
CR
IC
PS
IE
ROE
CG
PE
PC
PI
AT
TB
PLANNING
CLASSROOM EVENTS
PUPIL PURSUITS
BACKGROUND
CONTENT
MEANS OF INSTRUCTION
OUTCOME

Figure 15. Overall variables and relationships in the revised model of pedagogy.

study of pedagogy. The revised model's strength lies in the inclusion of content variables, in the details of planning and classroom events, and in the use of pupil engagement as an interim variable between what is done in classrooms and pupil outcomes. However, as we are completing this task we would like to make three comments.

First, the model building activity as an intellectual task has proven to be very challenging. It has forced us to rethink several ideas about teaching and learning and has raised several questions about our ability to represent teaching situations. We tried to be comprehensive in selecting elements and to deal with processes and relationships between elements. In doing so we had to reflect on our assumptions and beliefs about teaching

Second, although we believe our model is an improvement over prior conceptions of teaching, the difficulties we have in talking about classroom teaching of mathematics are more clear to us now than before we started. Some of our difficulties are definitional. For example, at one level of discourse we can talk about motivation or engaged time. However, for a model each idea requires much more detail and, in some cases, we have been unable to provide this detail. Some problems deal with relationships between variables. One would assume that variability on one element (e.g., planning) should affect another element (teacher action). The expression of such variability is not as clear as we thought would be.

Third, the assumption that variability exists must be demonstrated by scaling each variable. Educational researchers face many difficulties in trying to scale the variables of interest in such a model.

Of course, what we have not yet accomplished has become apparent. We have not captured in this still static description of classrooms, the actual dynamic nature of schooling. It is possible to use a static model and predict how it will change over time (how the dynamics of schooling are likely to increase or decrease the importance of various elements, include new elements, or exclude others over time). This will be essential, if we are going to deal with schooling as a social function and describe the episodic nature of instruction.

Another problem is with the variable engaged time; its importance is central to our model. Although we think engaged time is a major improvement over other conceptions of pupil actions, it is a very inadequate proxy for what students actually do.

Next, our model fails to deal with two important variables associated with schooling. The first is the capability of teachers to organize and manage pupils and resources (including time and the way individuals interact with each other) within the dynamic situation of schools. Second, we have viewed schooling from the teacher's perspective instead of from the pupil's. We could use their expectations as well as the teacher's expectations to identify variables.

In conclusion, we believe the revised model of pedagogy presented in this chapter will help scholars to study the teaching of mathematics. However, it should be viewed as an initial first step leading to the evolution of better, more comprehensive models.

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